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Sensor Unit and Sensor for Such a Unit

The present invention relates to a sensor unit as well as a sensor for such an unit according to the preamble of patent claim 1 and the preamble of claim 6, respectively.

It is intended to realize a unit for various sensoric arrangements or sensors for the detection of dynamic air gap changes with a general design concept, where the unit comprises shelf parts or ready-made sensors.

The invention generally serves applications in the area of mechanical engineering, yet particularly for brake and driving-dynamics systems in the automotive industry, and here primarily in the application sector of controlled systems with brake intervention like ABS and TCS. The main application sector, however, is the employment for ESP (driving stability control systems) and SWT (Sidewall Torsion, in which, for the determination of wheel forces and of wheel speed, the tire sidewall deformation of an motor vehicle wheel is measured via sensors and evaluated).

A specific tire suitable for SWT and an SWT sensor, respectively, are known from DE 196 20 582 A1 and DE 196 20 581 A1. Also known in the prior art are magnetically active machine parts for air gap modulation, in which basically all permanent-magnetic or ferromagnetic parts can be utilized, which are moved in the direction of the air gap in dependence on a physical quantity to be measured. Usually incremental encoders are used for this purpose. There is a distinction between ferromagnetic and permanent-magnetic encoders. Ferromagnetic encoders are, for

example, toothed wheels, toothed washers, toothed rings or hole-punched discs. Permanent-magnetic encoders are usually ring-shaped or circular arrangements of successive north/south pole areas embedded in rubber or some other mechanical carrier.

Substantial examples for the use of magnetized encoders are magnetized wheel bearing seals for an ASB system ("Active Sensor Bearing") for the detection of the wheel speed and the magnetized vehicle wheel, already mentioned above, for the detection of dynamic forces according to the SWT principle (Sidewall Torsion Sensors).

Sensor arrangements for the detection of air gap modulations by means of an encoder are generally known. For instance, they also serve for the determination of crankshaft and camshaft positions in motor vehicle engines. In another classical case of application, the measurement of wheel speeds, an incremental encoder track periodically modulates the magnetic field strength in the air gap between two fixed values. An additional change of the kinematics between the sensor and the encoder through dynamic forces during driving operation and the herewith additionally occurring modulation of the field strength is undesirable in this application and is suppressed during signal-conditioning.

To this end, the so-called active sensors known from the prior art for ABS wheel speed detection contain an internal amplifier/trigger circuit that effects that, regardless of the air gap dynamics, always a square wave signal with two constant amplitudes is generated, whose edge change follows the encoder track.

For the detection of driving-dynamical states (ESP) of a motor vehicle, e.g. during cornering, it is suggested, for example in DE 44 42 355 A1, to draw on the value of an elastic axle deformation and, for its measurement, to use the width of the air gap between a wheel speed sensor and its respective encoder.

For the determination of longitudinal and lateral forces, it is known from DE 44 35 160 A1 to detect as well the phase of two wheel speed sensor signals as their variable signal amplitudes on a magnetically encoded tire via air gap deformations.

The objective of the present invention is to provide a concept equally suitable for all above-described sensor types, in which concept modular sensor units are formed, whose basic system is suitable for all sensors. It is further the objective of the present invention to create a sensor, in particular an SWT sensor, suitable for this concept of the formation of common units.

This objective is achieved, according to the invention, by means of the features of the patent claims 1 and 6, respectively.

A first inventive idea consists in generally designing future sensor units constructively in a way that their housing dimensions and outer shape is identical or nearly identical with sensor elements already in use for the production of active ABS wheel speed sensors (ready to use with cable and plug). This yields the advantage that, for the introduction of series production of novel sensors, e.g. SWT sensors, the same production tools can be used as for active wheel speed sensors.

Due to the great variety of different series programs for active sensors, there is an abundance of already existing different shape designs and constructive embodiments of active wheel speed sensors with the corresponding production tools, from which matching shapes can be steadily adopted for SWT sensors. In this way, the development expenditure is minimized, and the advantage is attained that also small SWT equipment numbers can be served economically. This basic thought also applies to future active sensors for wheel speed detection.

Further on, using the above concept, an inventive arrangement is described with which air gap modulations of any kind can be detected so that with these, beside the wheel speed, also air gap changes can be measured as a function of deformation forces. These sensors are particularly suitable for the realization of the sidewall torsion concept, yet as well for the realization of sensor systems for ESP based on DE 44 42 355 A1.

Further advantages and preferred embodiments of the present invention arise from the subclaims as well as from the following description in connection with the attached drawings. In the drawings,

Fig. 1 a shows a basic structure of the inventive sensor unit;

Fig. 1 b-c show different variants of sensors based on the same concept;

Fig. 2 a-b show schematic illustrations of sensor circuits with functional blocks; and

Fig. 3 a-b show the course of signal currents J_1 and J_2 over the time.

In connection with Fig. 1 a-d, at first a general concept for the standardized design of units for the active-sensor scanning of encoders is described, which are processed into ready-made sensors (probes) or which comprise common modular units according to the invention, respectively.

Fig 1a shows an outer housing shape or basic structure, respectively, of a general sensor element according to the inventive design concept. Here reference numeral 1 identifies a housing or head 1, preferably made of plastic, in which always some magneto-electric converter element is embedded. 2 identifies a housing, preferably made of plastic, that further on will also be called body 2. In body 2, there is always embedded some electronic signal processing circuit. The intended application determines what converter element is contained in head 1 and what signal processing circuit in body 2. A permanent 4-pole electric connection 3 extends between head 1 and body 2. For a 2-wire connection to a control device, a pin 4 serves as signal output and a pin 5 for the supply with operating voltage.

Figures 1b, 1c, and 1d show the general housing shape according to Fig. 1a combined with three differently sized magnets 6, 7, and 8. These magnets serve for the demand-assigned different magnetic pre-load of electro-magnetic converters in head 1. Following the inventive thought of the design concept, three different magnets 6,7,8 have fixed dimensions so that general design variants exist now, whose content can be exchanged or adapted in head 1 or body 2 according to the application.

In an advantageous application, the constructive dimensions of the design variants correspond at the same time those of already existing active wheel speed sensors.

A further advantage of the inventive design concept consists in always realizing the following four interface properties. A 2-wire connection to the control device, operation with a wide range of uncontrolled supply voltage, load-independent current as carrier of the output signal as well as a continuous frequency resolution up to the standstill of the encoder.

Preferably, magneto-electric converters are exclusively used which are based on XMR technologies (concerning this, see Verlag VDI-Technologiezentrum, Düsseldorf, "Technologieanalyse Magnetismus", Vol. 2). Here particularly AMR technology (anisotropic magneto-resistance) and GMR (giant magneto-resistance).

The design variants are consistently used with a significant advantage as follows: The variant according to Fig. 1a in combination with permanent-magnetic encoders, the design variant according to Fig. 1b in combination with ferromagnetic encoders, the design variant according to Fig. 1c in combination with ferromagnetic encoders, and the variant according to Fig. 1d in combination with permanent-magnetic encoders.

Applications of the new design concept according to the invention are, among others, active wheel speed sensors with digital offset compensation according to patent application DE 198 15 084 A1, in which the head 1 comprises a magneto-resistive bridge and a Barber pole structure as well as an ASIC for digital offset compensation. ASICs are integrated circuits (ICs) specifically designed for the application.

Additionally, the invention is suitable for active wheel speed sensors with transmission of additional information and a novel data protocol according to DE 196 34 715 A1. A head 1 with magneto-resistive bridge and Barber pole structure, in which an IC or ASIC is employed for the recognition of direction and for the diagnosis of the air gap, is also conceivable.

Another conceivable application of the inventive sensor unit is an active sensor for the simultaneous detection of wheel speed and dynamic air gap deformation. Such a sensor can be utilized with a significant advantage for ESP or SWT, respectively. In this case, the sensor preferably includes a head 1 with a magneto-resistive bridge and a body 2 with an ASIC, in particular of the type UA1272. Preferably, this sensor is designed according to one of the design variants according to Fig. 1 b-d.

Subsequently, such a sensor according to the invention as well as its adaptation to the inventive concept of the sensor units is described in further detail. The intended components of realization are mentioned in the preceding paragraph. The variants of the constructive completion follow the guideline of the design concept claimed by the invention.

As previously explained, There are sensor elements for active wheel speed sensors, which can be integrated into the design concept and are currently manufactured in large numbers. To this end, Fig. 2b shows a schematic illustration of an electronic circuit with functional blocks of a n active wheel speed sensor, and Fig. 2a shows a schematic illustration of the sensor according to the invention. Both depictions show at the same

time the constructive allocation of the functional blocks into the superordinate design concept according to Fig. 1.

Preferably the same crystal module should be used for the detection of the air gap modulation that is already present as a standard component of sensor elements for active ABS wheel speed sensors and manufactured in large numbers. This yields the economic advantage that also small SWT equipment numbers can be served more economically. At the same time, the total number of crystal modules produced is increased, which become cheaper that way.

Both heads 1 contain a magnetoresistive bridge circuit 9 of the same type. The magneto-electric converters 9 are, via an air gap not depicted here, magnetically coupled to a permanent-magnetic encoder track 10, which is preferably arranged in the sidewall of a magnetized tire or in a magnetized wheel bearing seal. The heads 1 are connected to the bodies 2 through the mentioned 4-pole connections 3. To the respective control device, there is the above-mentioned 2-wire connection via pin 4 and pin 5.

The voltage supply V_{cc} is established via the respective pin 5 from an electric control or regulating unit for the brake system. The signal processing circuits contained in bodies 2 differ by the schematically shown units 12 and 13 so that the signal currents J_1 and J_2 are significantly different, too.

In the known active sensor according to Fig. 2b, every fluctuation of amplitude, caused by dynamic air gap deformation, is suppressed by an amplifier or trigger stage, and the signal is shaped into an accurate, load-independent rectangular signal current J_2 with two constant amplitudes so that the transmitted

information is limited to the wheel speed which is mapped in the sequence of edges.

In the inventive arrangement according to Fig. 2a, however, there is located an electronic circuit 12 amplifying and processing the signal so that a signal current J_1 is supplied to the control device 11, from which signal current additionally, beside the wheel speed information 14, the gauge of the amplitude can be gathered as a measurement for the thickness of the air gap 15 and the phase relation 16 to a reference signal.

Figs. 3a and 3b clarify once more the differences of the signal currents J_1 and J_2 between the known active sensor of Fig. 3b and the inventive sensor according to Fig. 3a under the same interface conditions to the encoder. Under the presumption of an air gap variation shown here, both sensors map the same wheel speed, however, only the inventive sensor additionally also the amplitude changing with the air gap width.

In an advantageous embodiment of the invention for the realization of an SWT sensor, the previously described arrangement can for instance be designed according to the following characteristics:

To this end, the SWT sensor has a magnetic sensitivity (output current amplitude/encoder field strength) of S = .75 mA/[kA/m], an output current amplitude range of J = 11 mA ± 4 mA lift, a terminal voltage range at pin 4 of V_{CC} = 5 to 16 V, and an output impedance of ≥ 10 kOhm.

The magnetized tire sidewall as encoder track can, for instance, be equipped with a pole pattern of 48 north/south pole pairs per 360° sidewall and with a magnetic field strength amplitude of .8 kA/m at 10 mm air gap.

In an advantageous embodiment of the invention for the realization of an SWT sensor, the sensor arrangement is realized according to the inventive design concept by utilizing the following units. Head 1 comprises a magnetoresistive bridge 9, body 2 includes an ASIC of the type UA1272. Preferably, the sensor is designed according to the embodiment of Fig. 1b, 1c, or 1d.